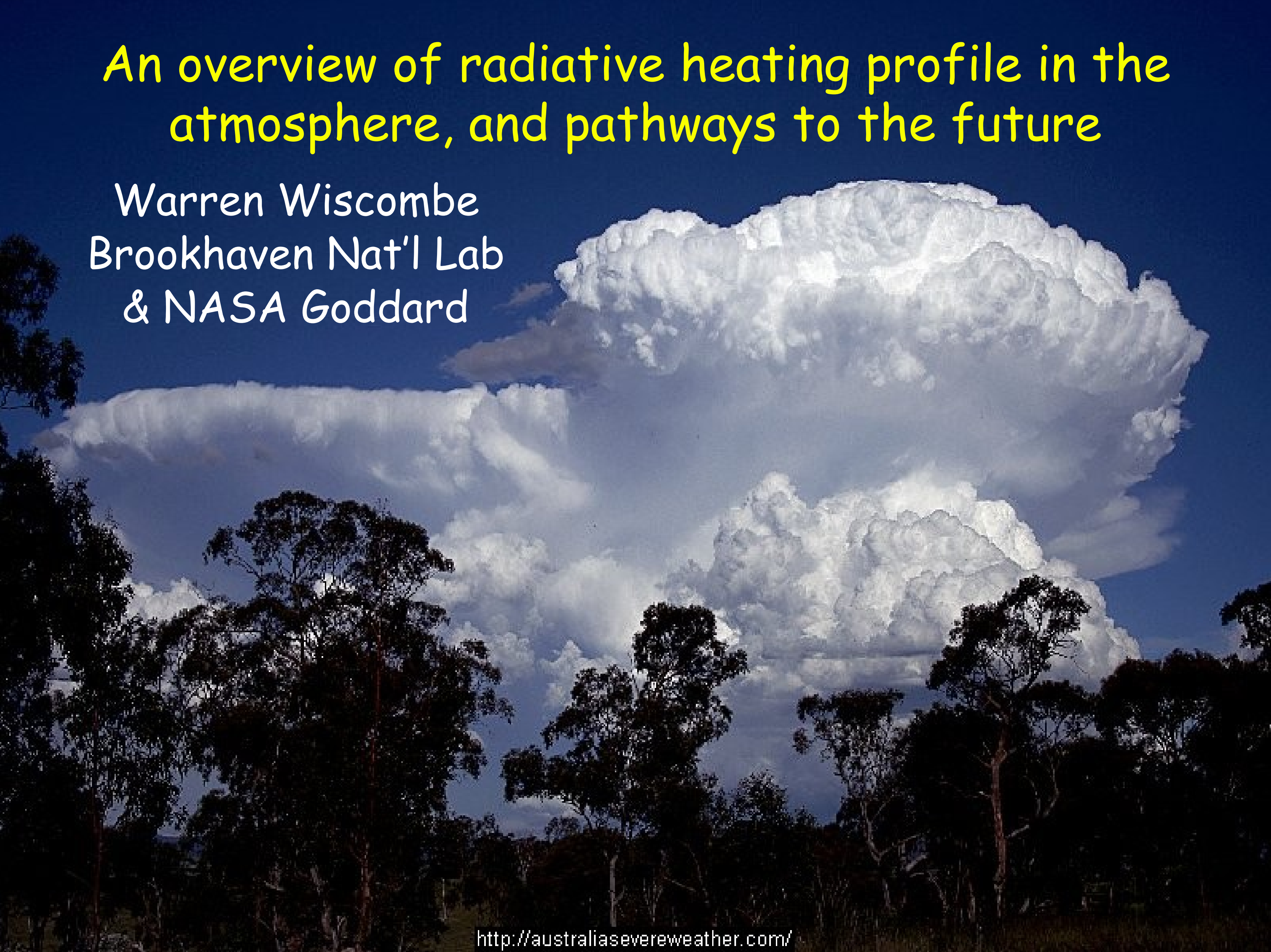
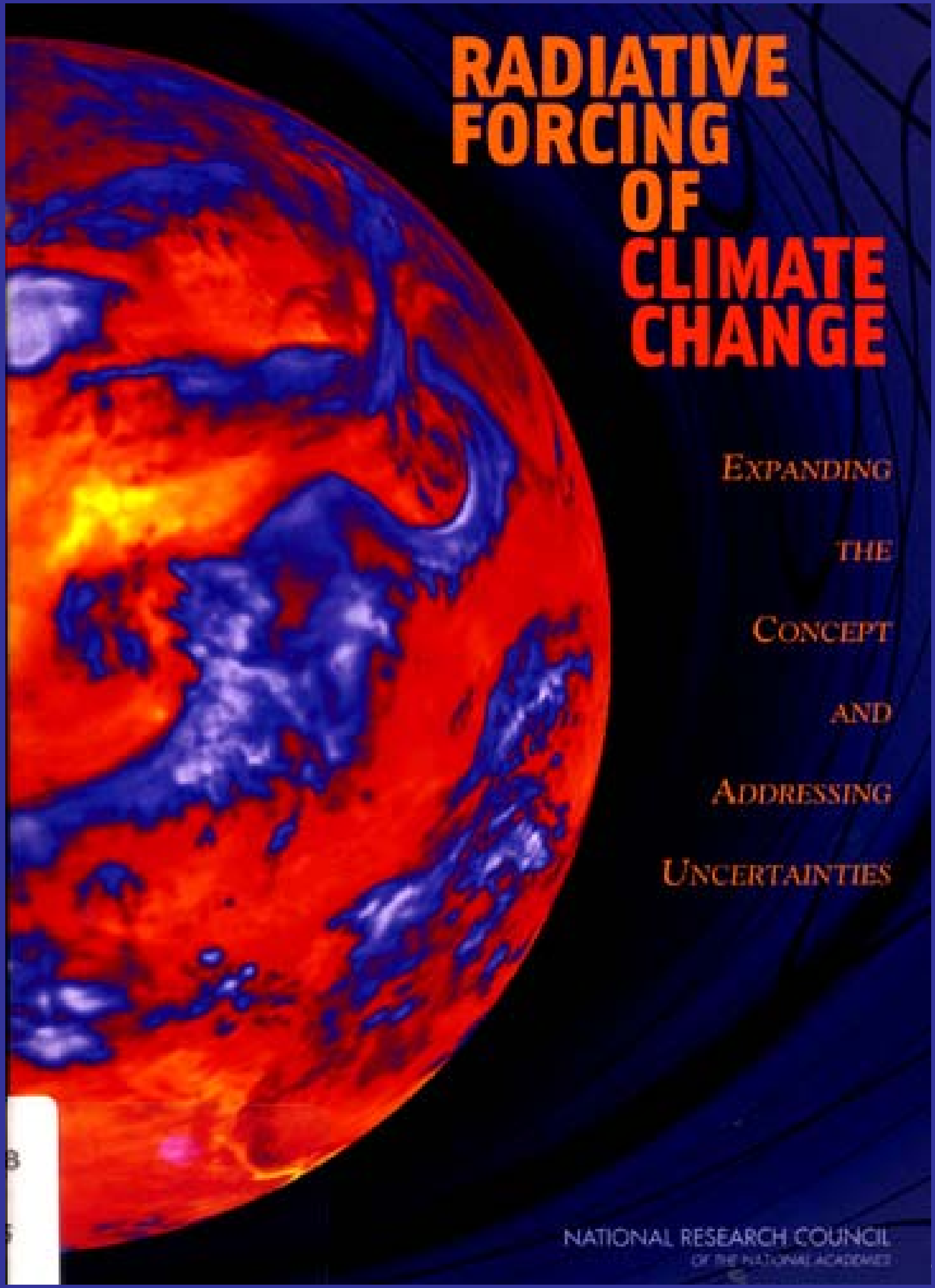
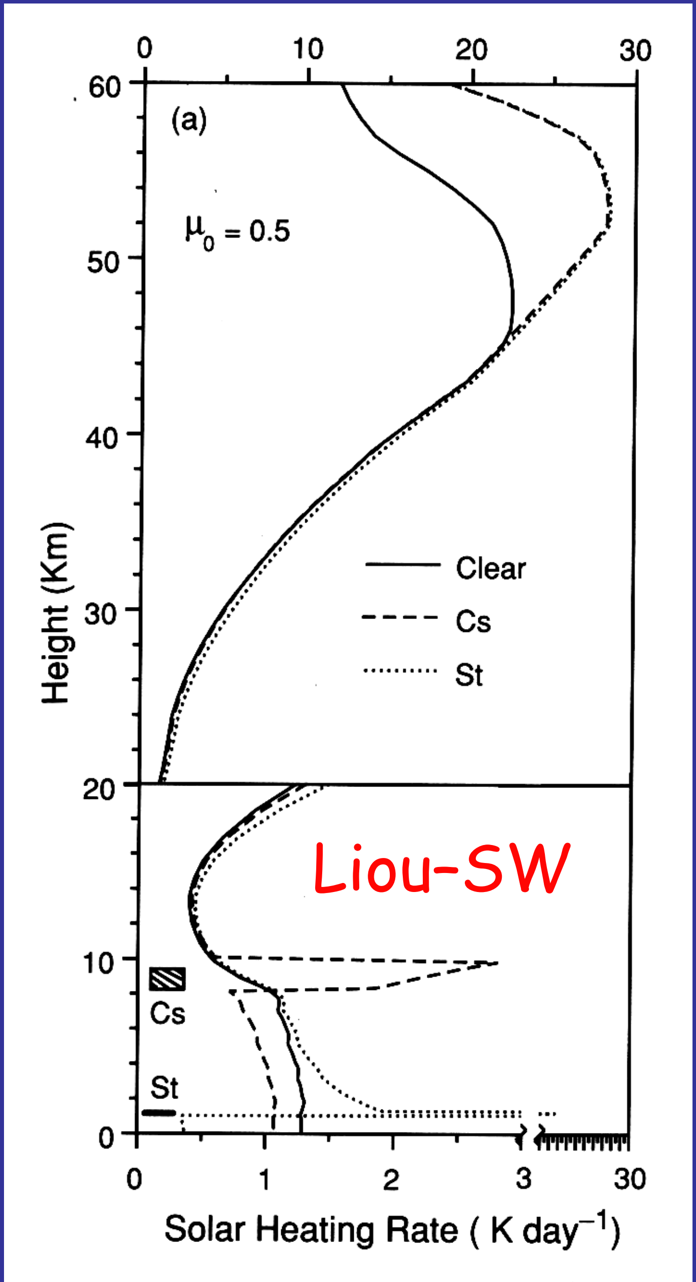
An overview of radiative heating profile in the atmosphere, and pathways to the future

Warren Wiscombe
Brookhaven Nat'l Lab
& NASA Goddard





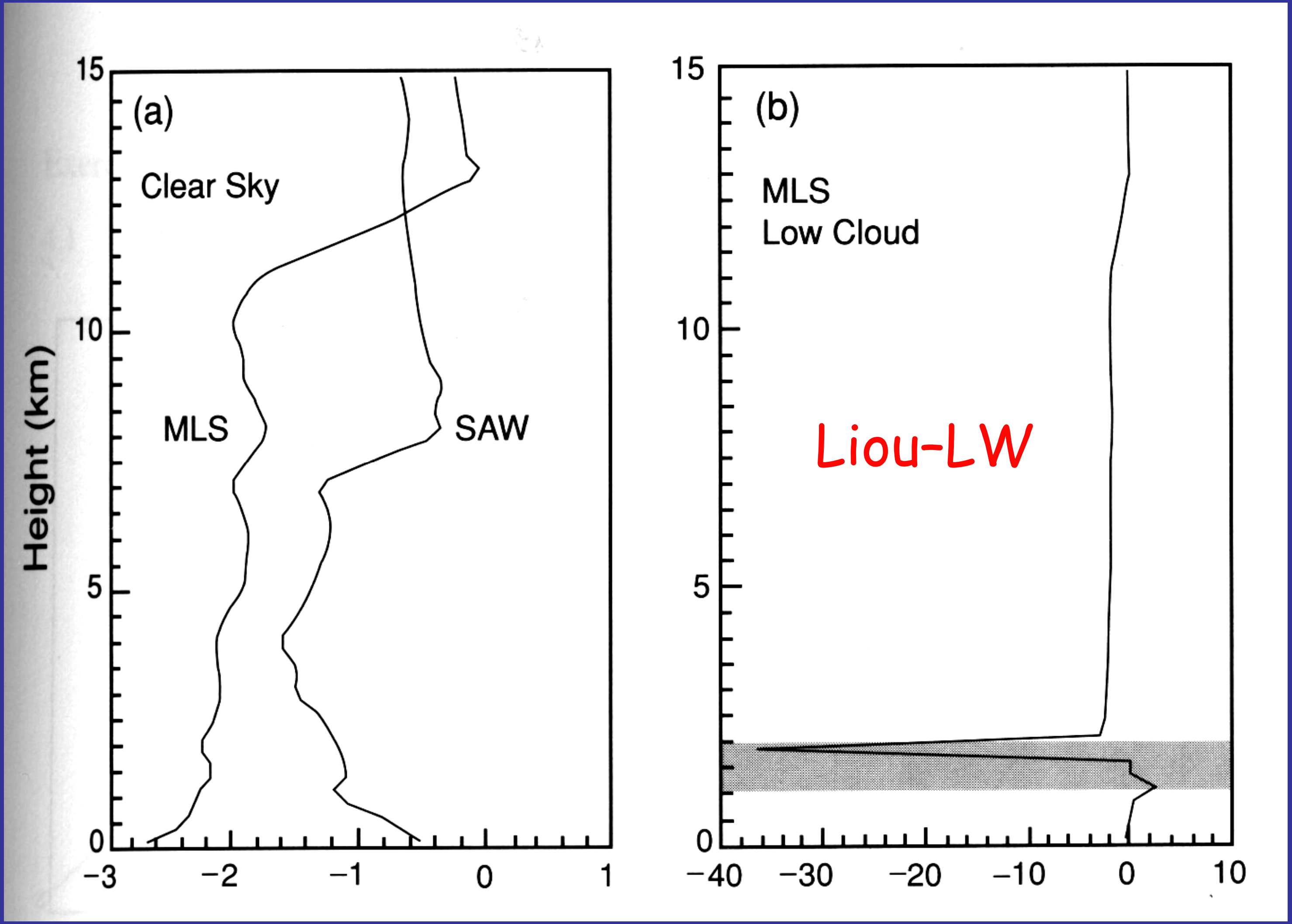
NAS report recommends expanding concept of radiative forcing to **<u>vertical</u>** and regional



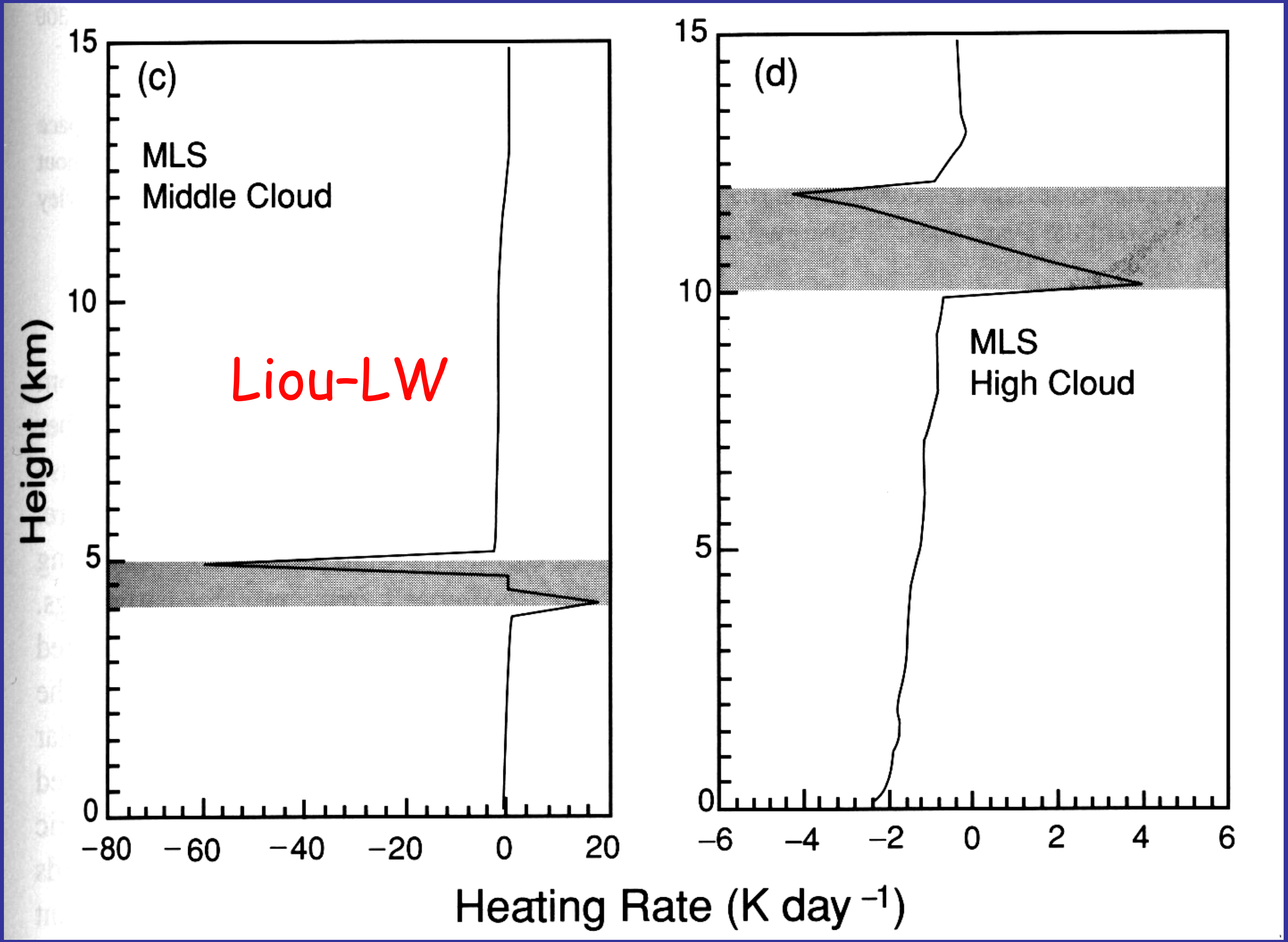
What do our standard texts say about radiative heating profiles?

- Very little — handful of graphs and equations
- Almost no measurements
- Few comparisons with latent and other forms of heating/cooling
- Emphasis on shortwave

LW values are generally double SW in clear sky, much larger than SW near cloud top



Mid- and high-level clouds are whipsawed with LW cooling at top and heating at base



We spend most of our effort on the SW heating...

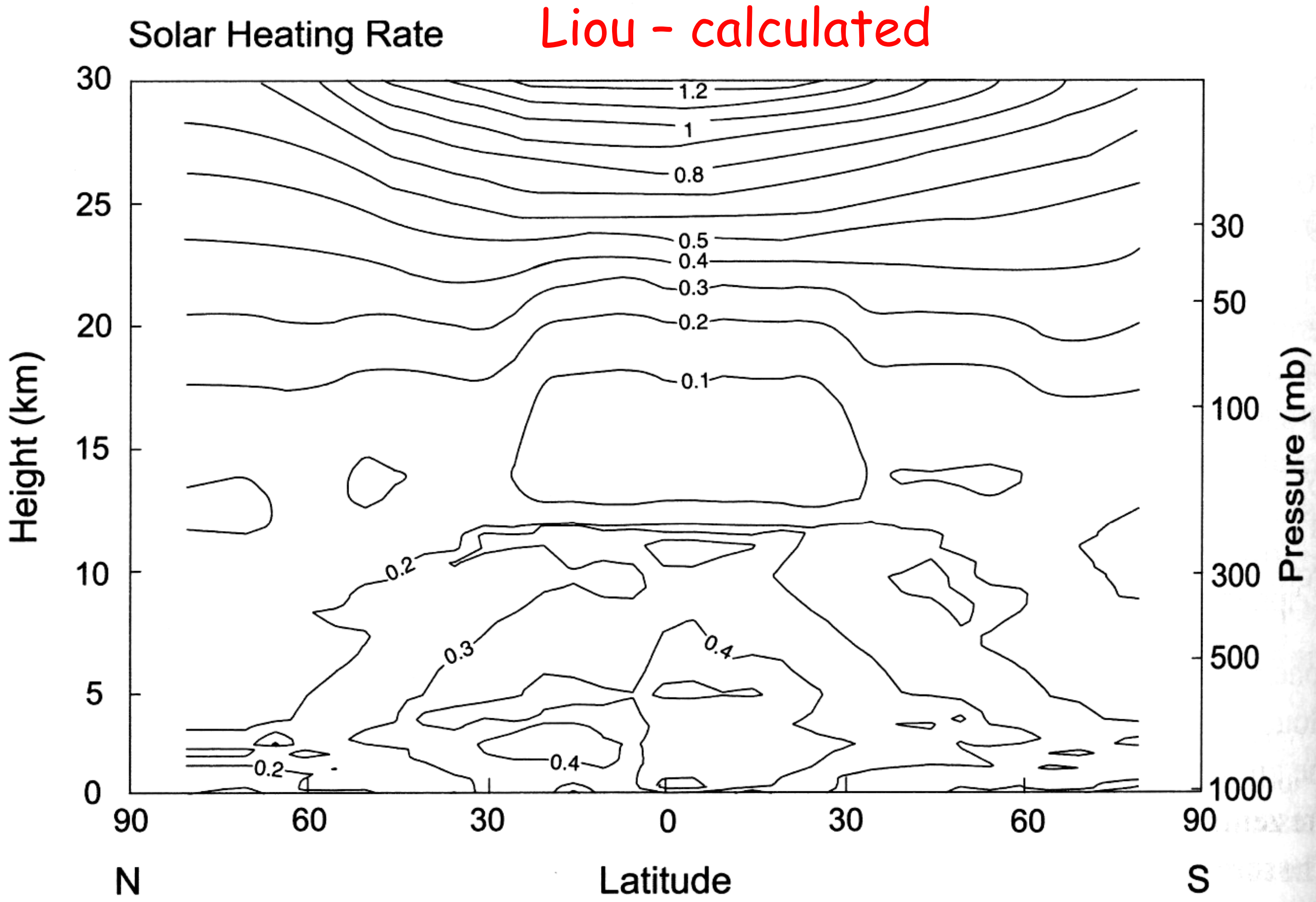


Figure 8.4 Annual meridional cross sections of the solar heating rate (K day^{-1}) of the atmosphere computed from a radiative transfer program using climatological temperature, cloud, gaseous, and surface albedo data. The input solar flux is 342 W m^{-2}. The contour line is 0.1 K day^{-1}.

but actually the LW cooling dominates so that the net heating is negative almost everywhere

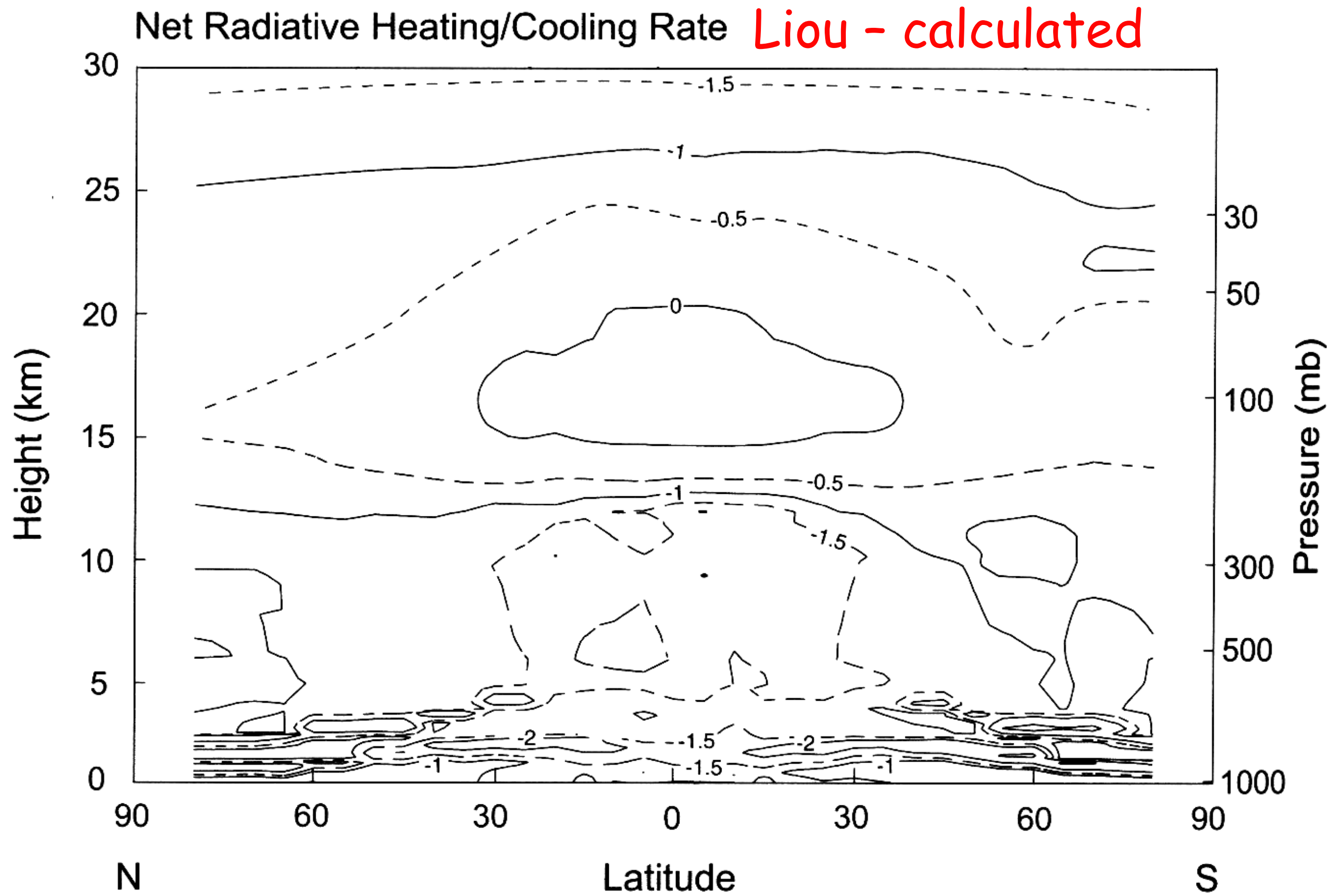
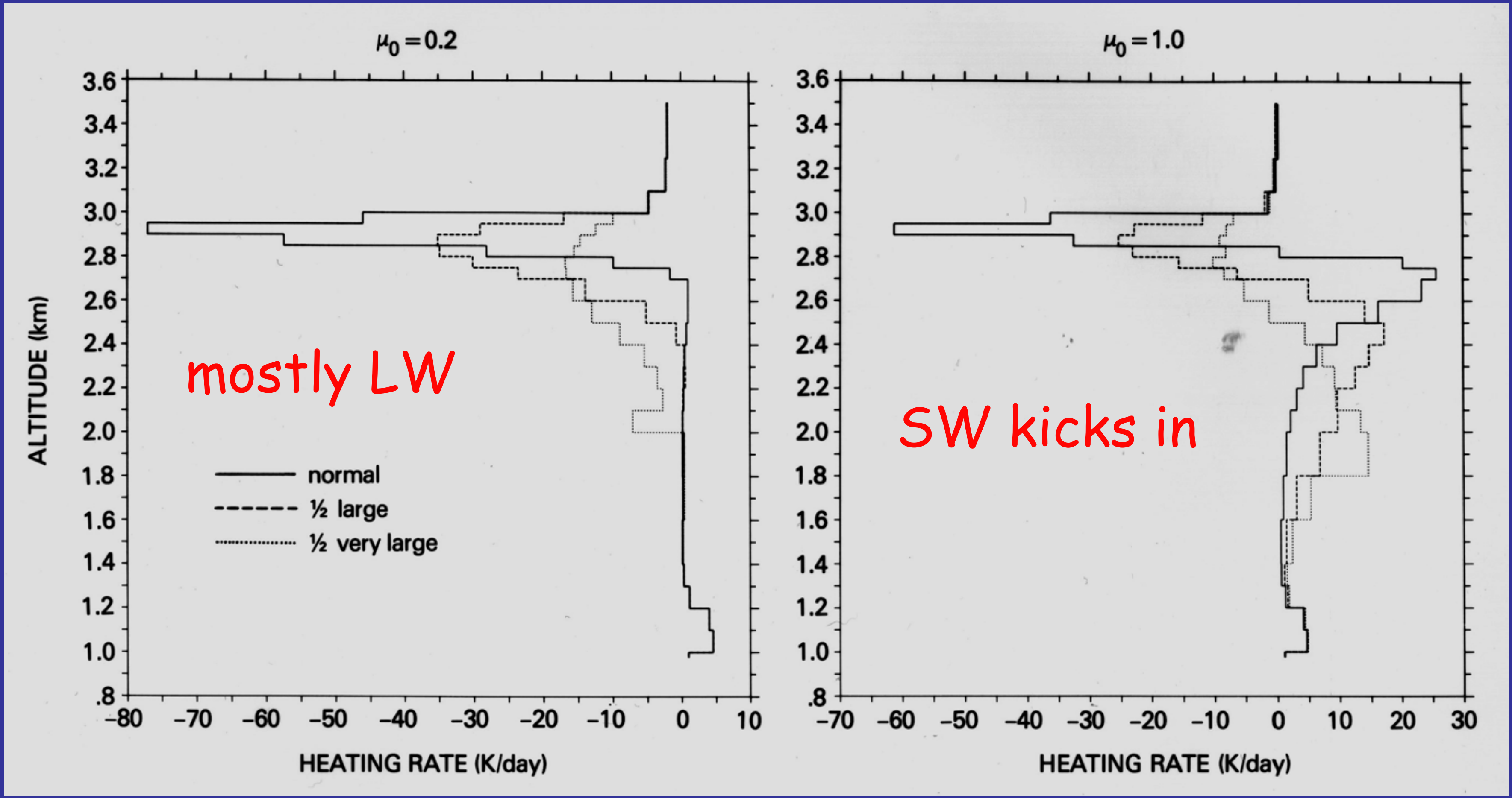
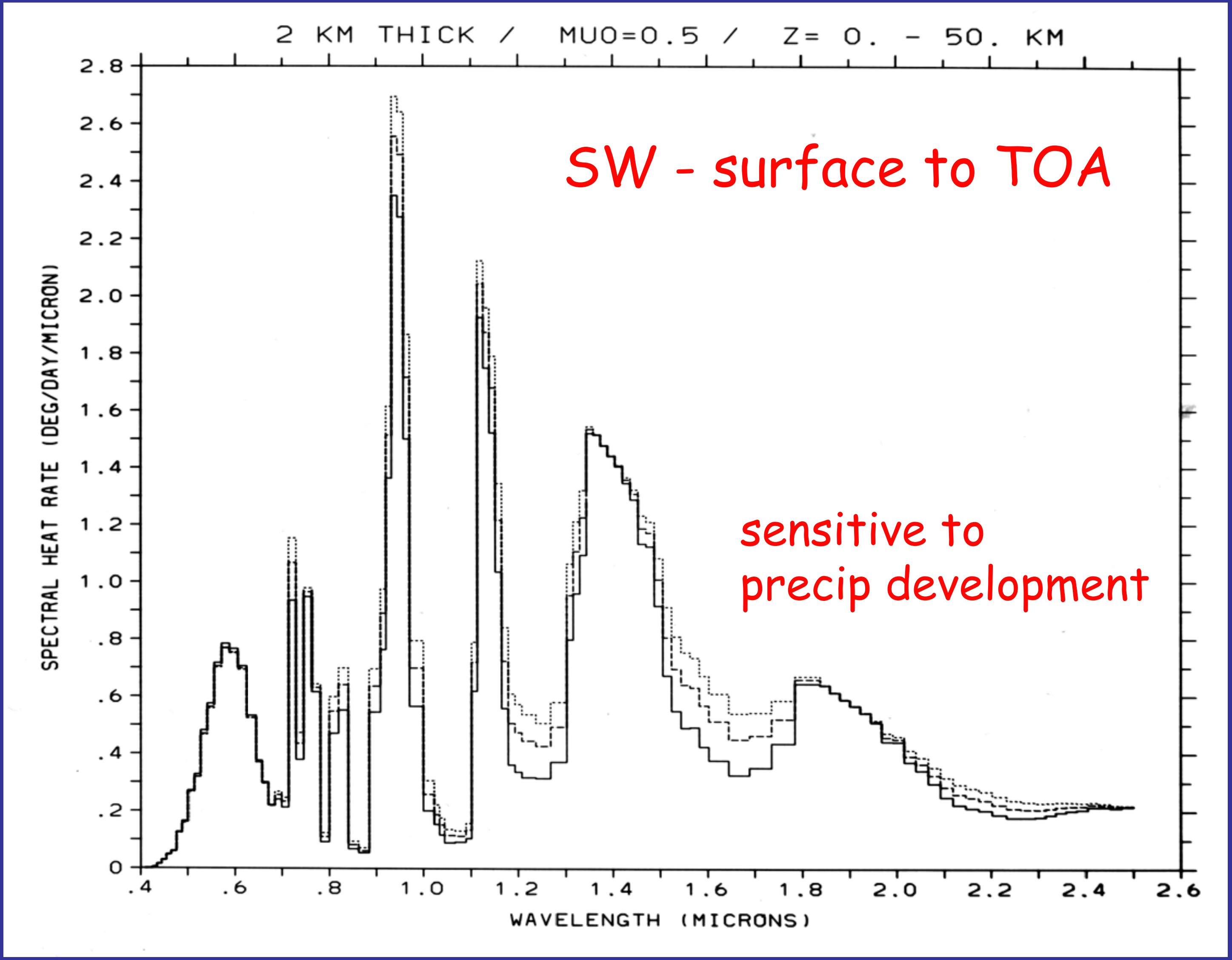


Figure 8.6 Annual meridional cross sections of the net radiative heating/cooling rate (K day^{-1}) of the atmosphere. The contour line is 0.5 K day^{-1}.

My ATRAD calculations from the early 1980s showed the tradeoff between SW and LW

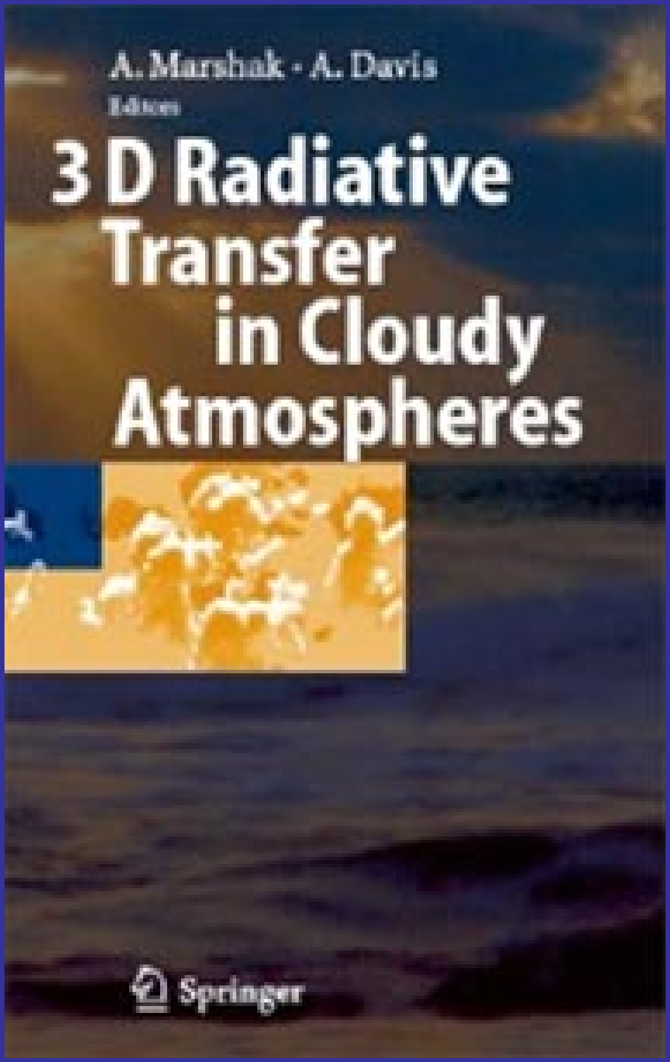


ATRAD produced NCAR-graphics plots of spectral heating for cloudy cases in 1970s



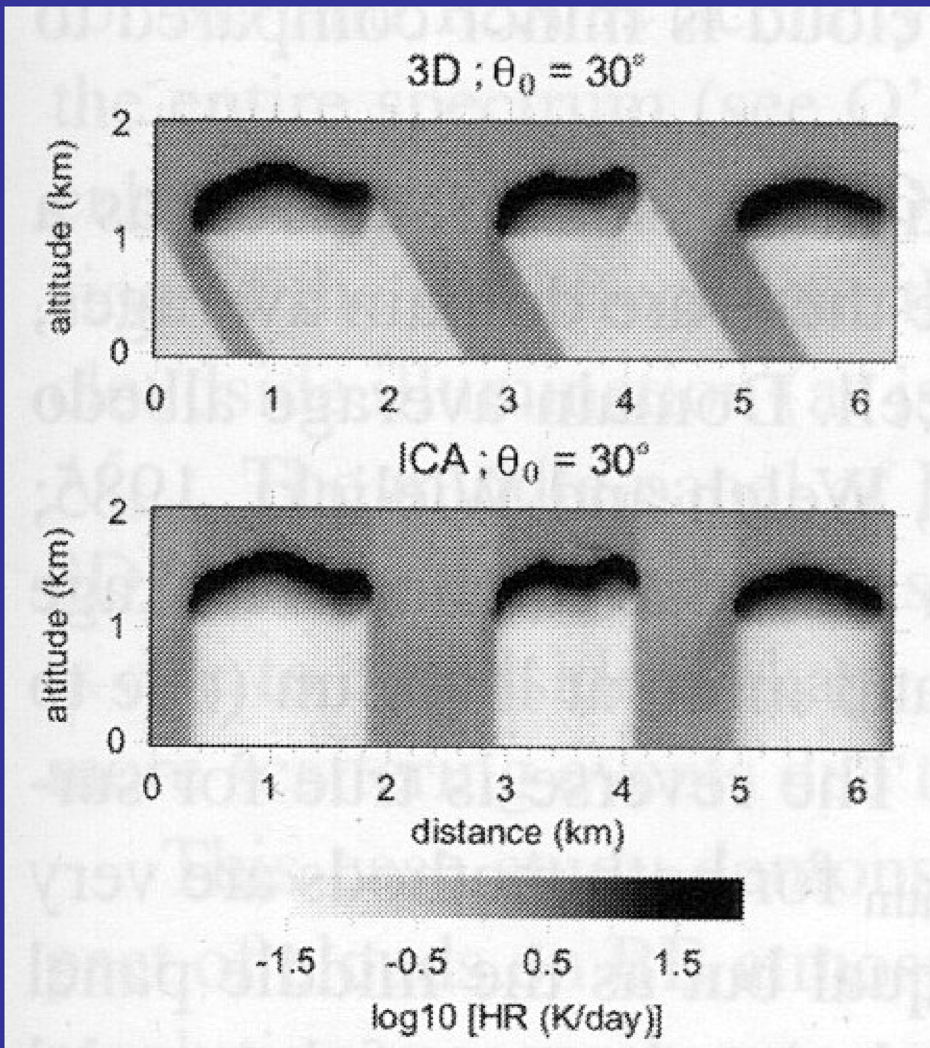
Now we leap to the present…

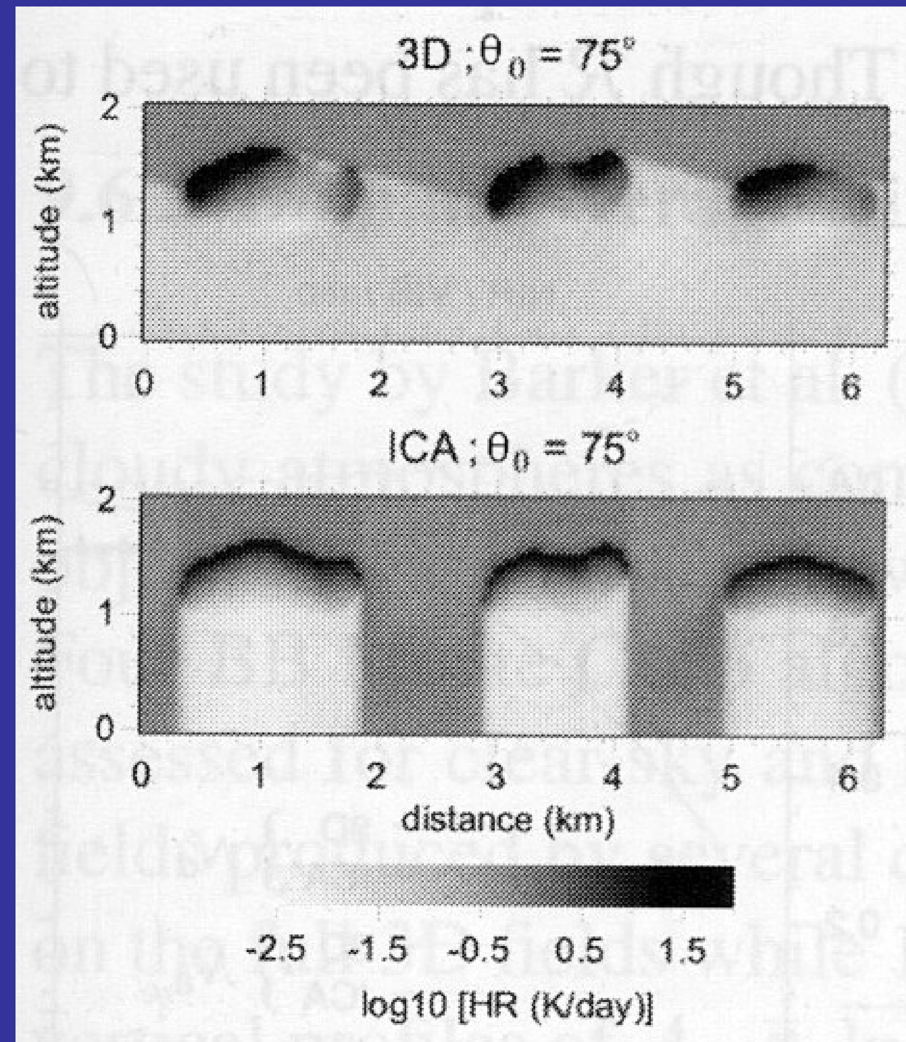
published 2005



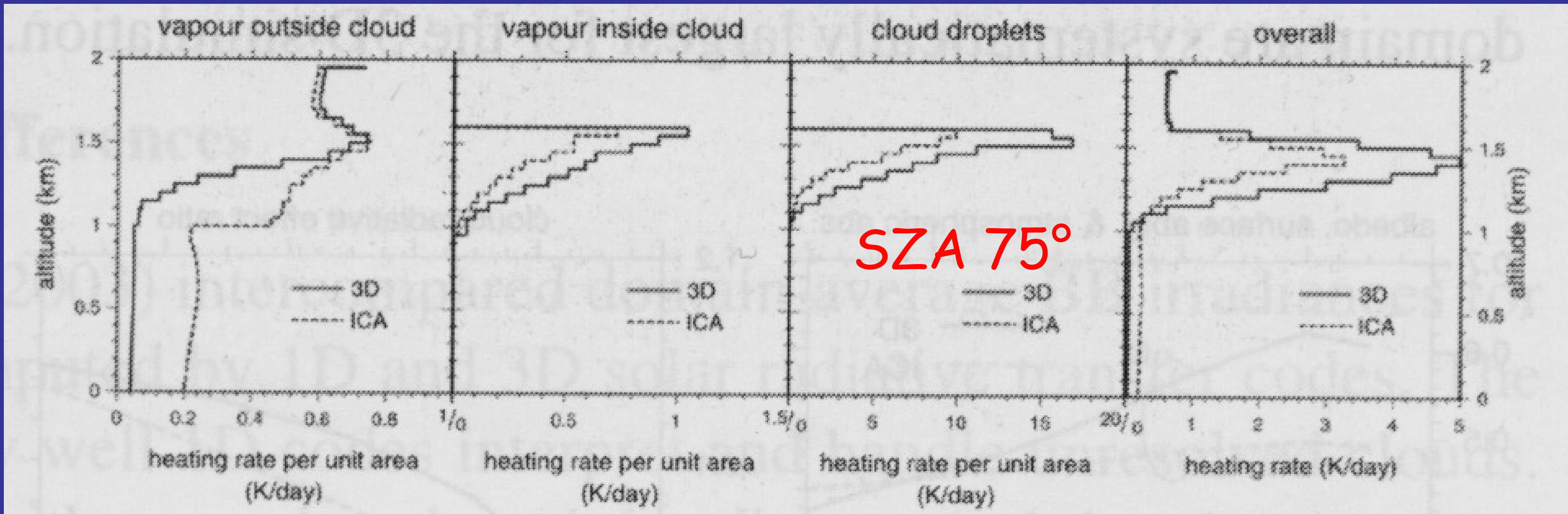
Barker 3D SW heating calculations for CRM clouds

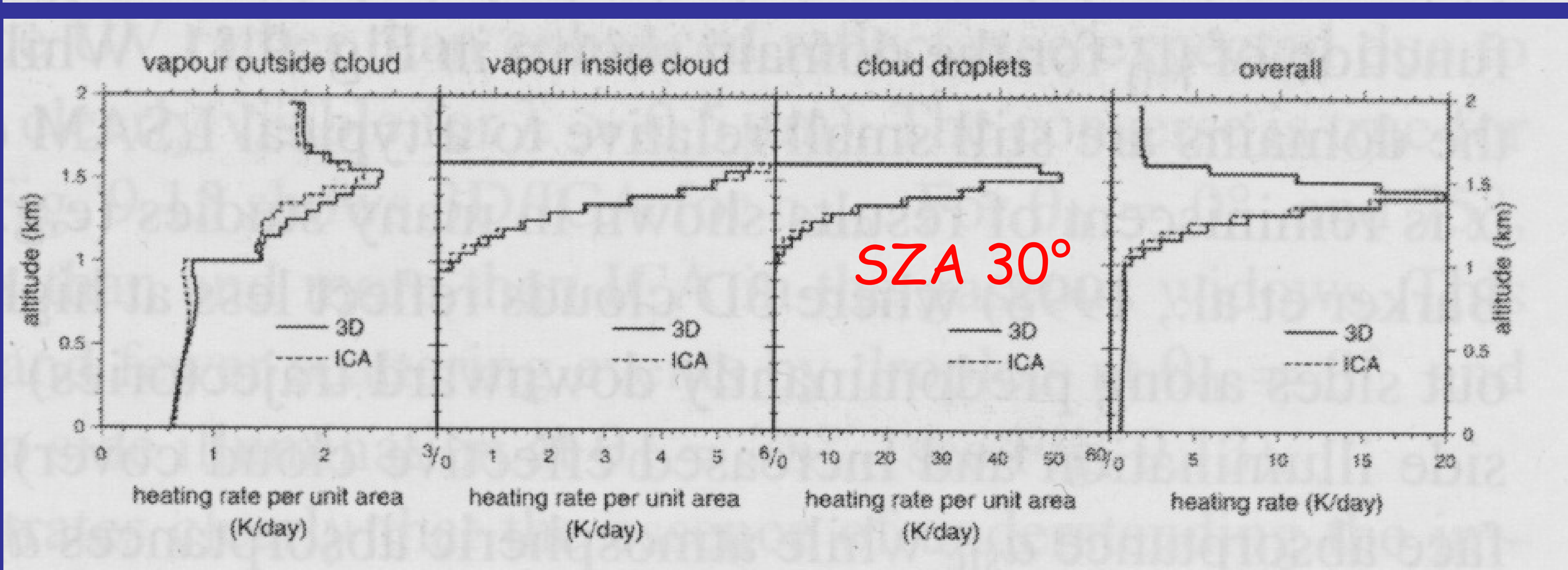
from Marshak/Davis 2006



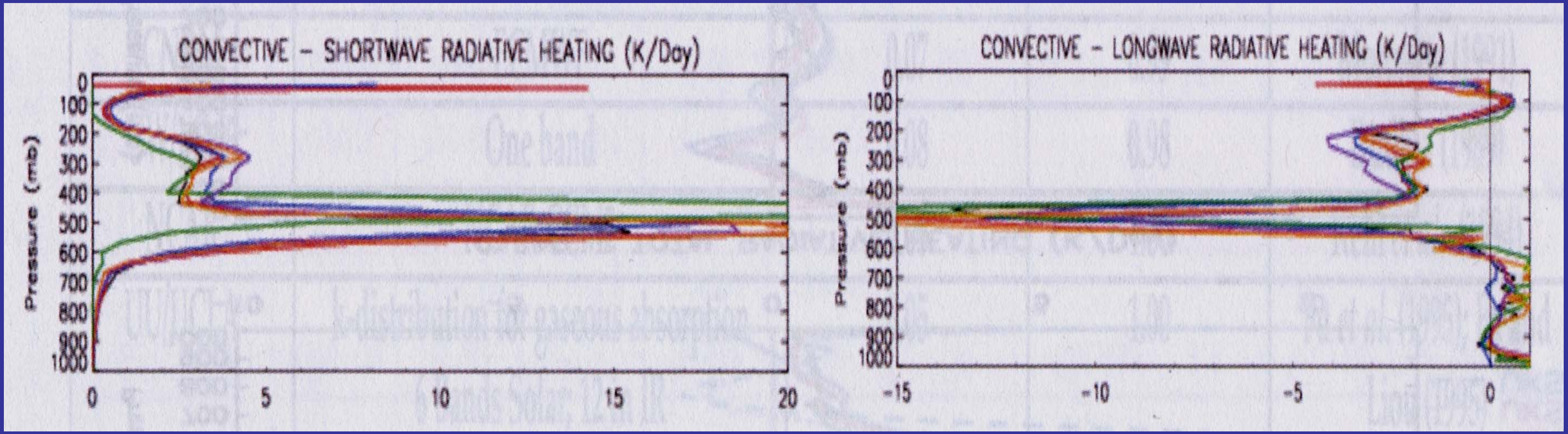


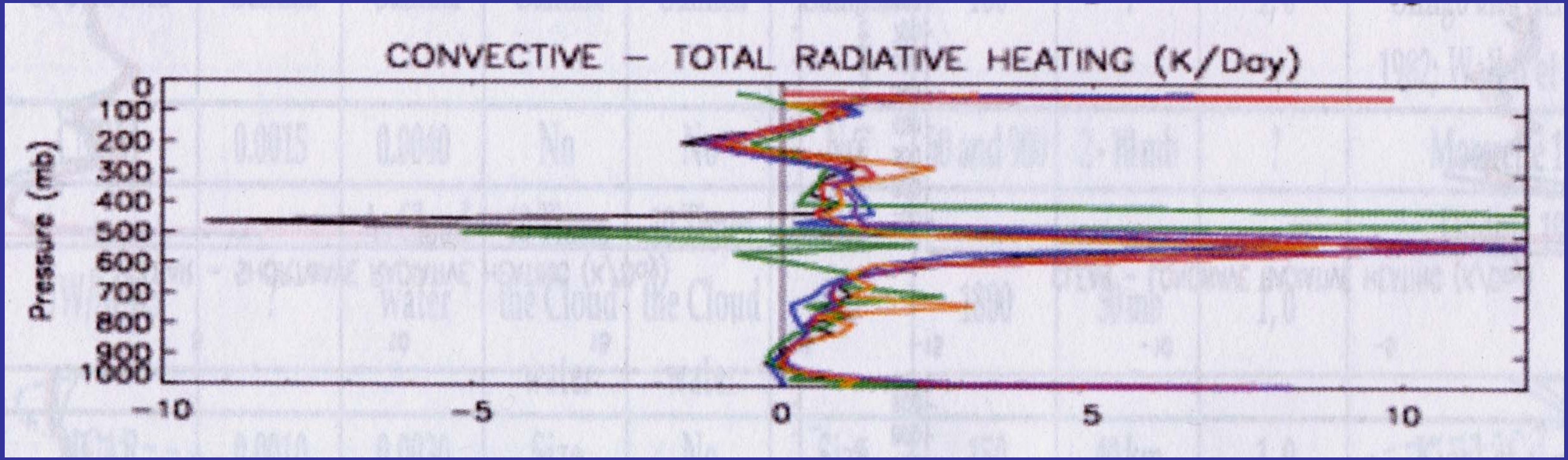
Domain averages for clouds from previous slide





Comparing many CRM rad'n models for a Goddard Cumulus Ensemble simulation (Tao)





Past attempts at measuring flux divergence

- Weinman -- top hat mean intensity meter
- Albrecht and Cox -- tried to make corrections for having single a/c and for "escaping photons"
- CAGEX
- Cess 5 sites
- ARESE I & II
- Niger

1D rad flux divergence related to mean intensity

$$\frac{dF}{dz} = 4\pi\,\alpha\left(\bar{I}_{\nu} - B_{\nu}(T)\right)$$

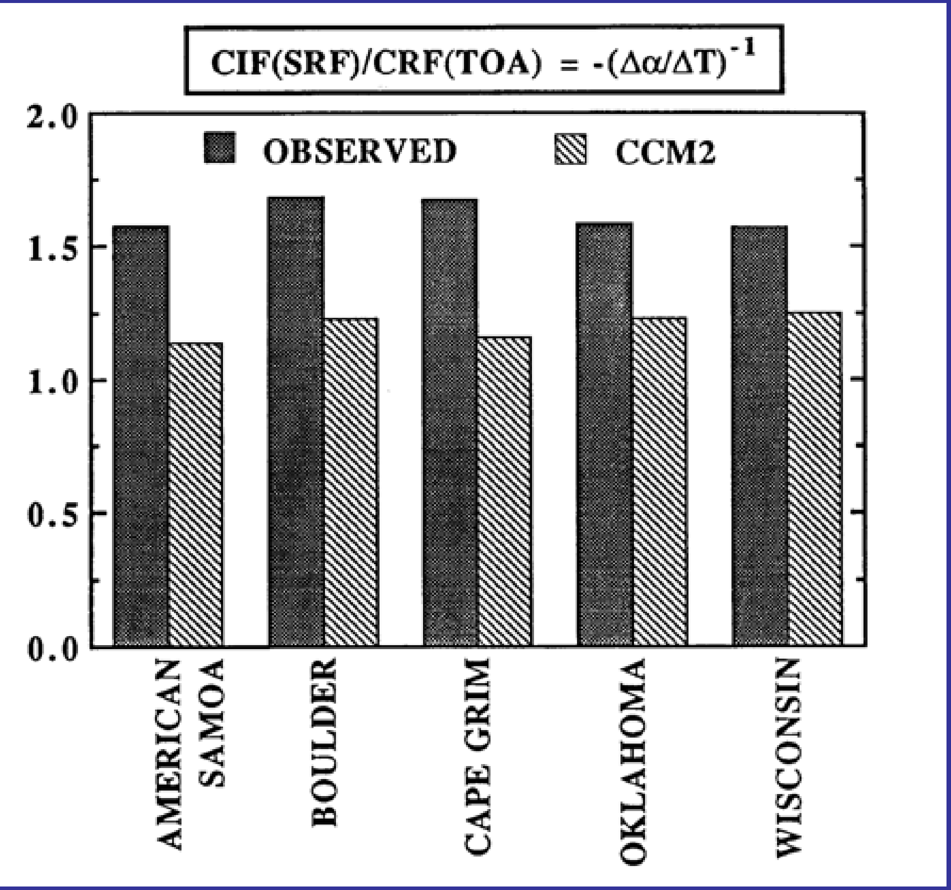
Thomas & Stamnes, Eq 5.77

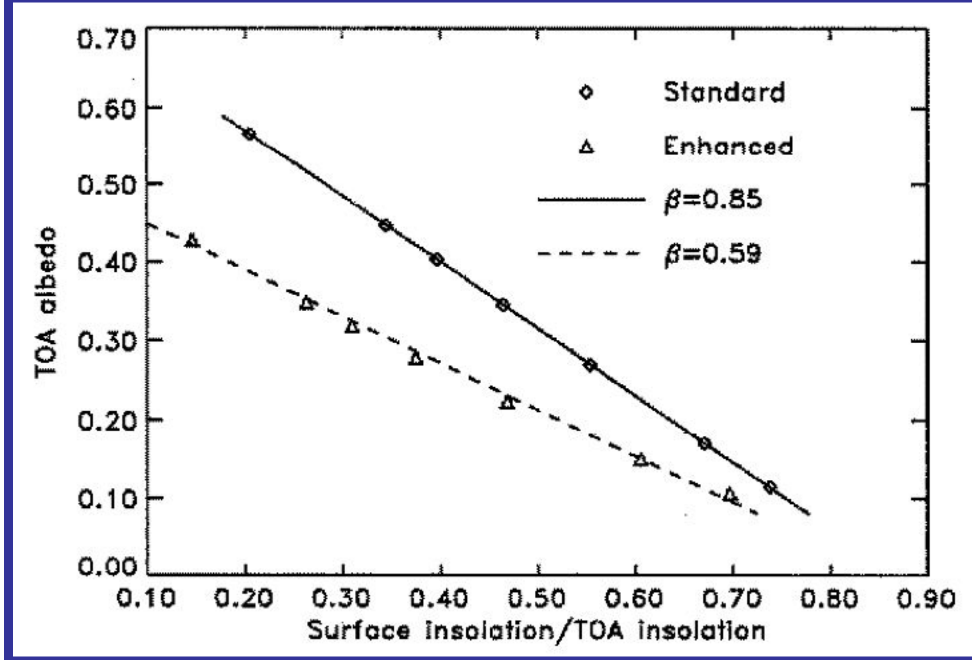
α = absorption coeff.

3D analogue?

Does this idea have any future?

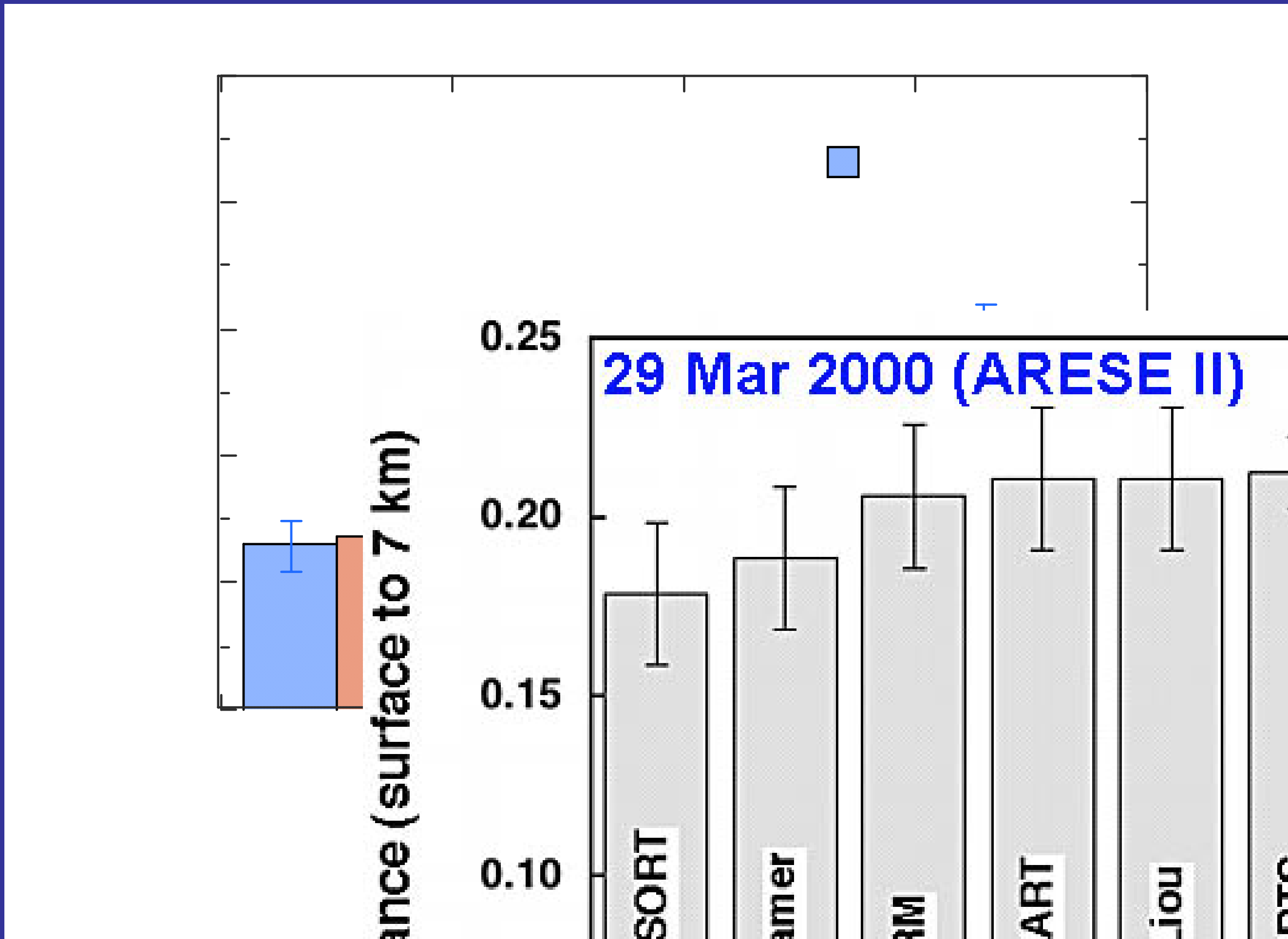
Cess: 5 sites and R_{TOA} vs surface transmittance

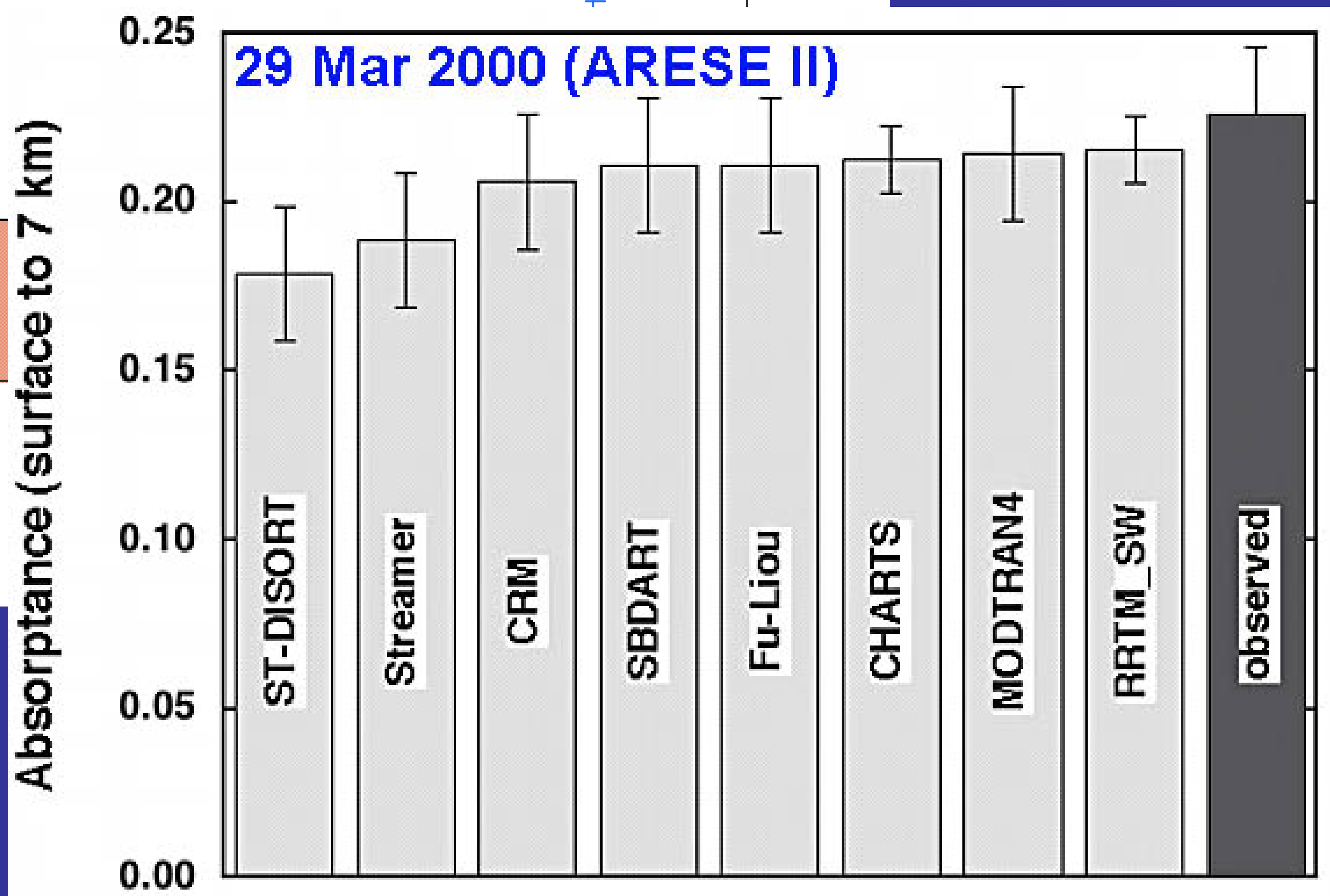




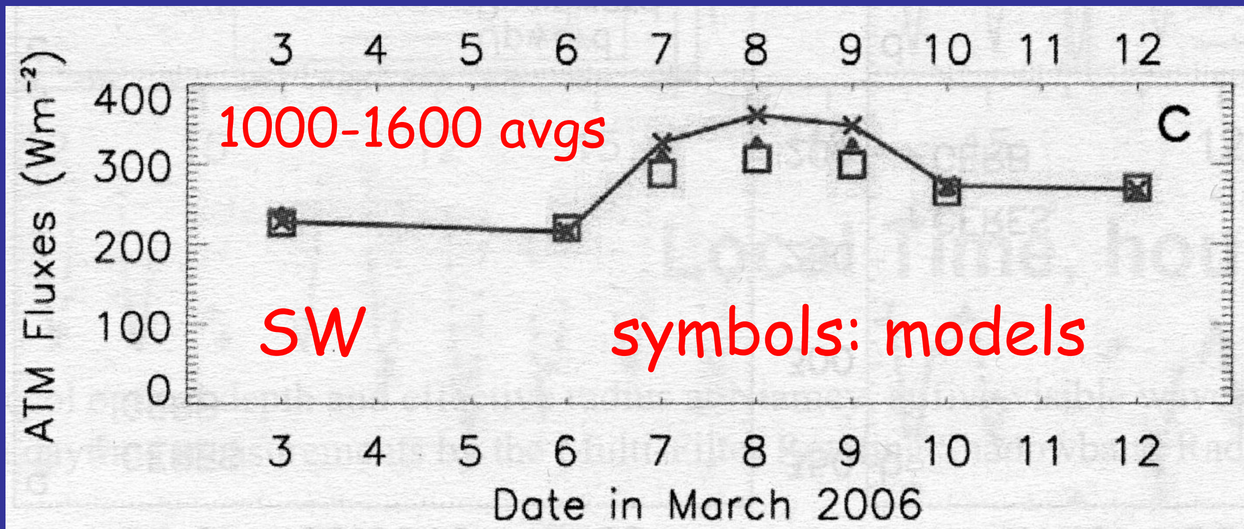
famous R vs T plot

ARESE II

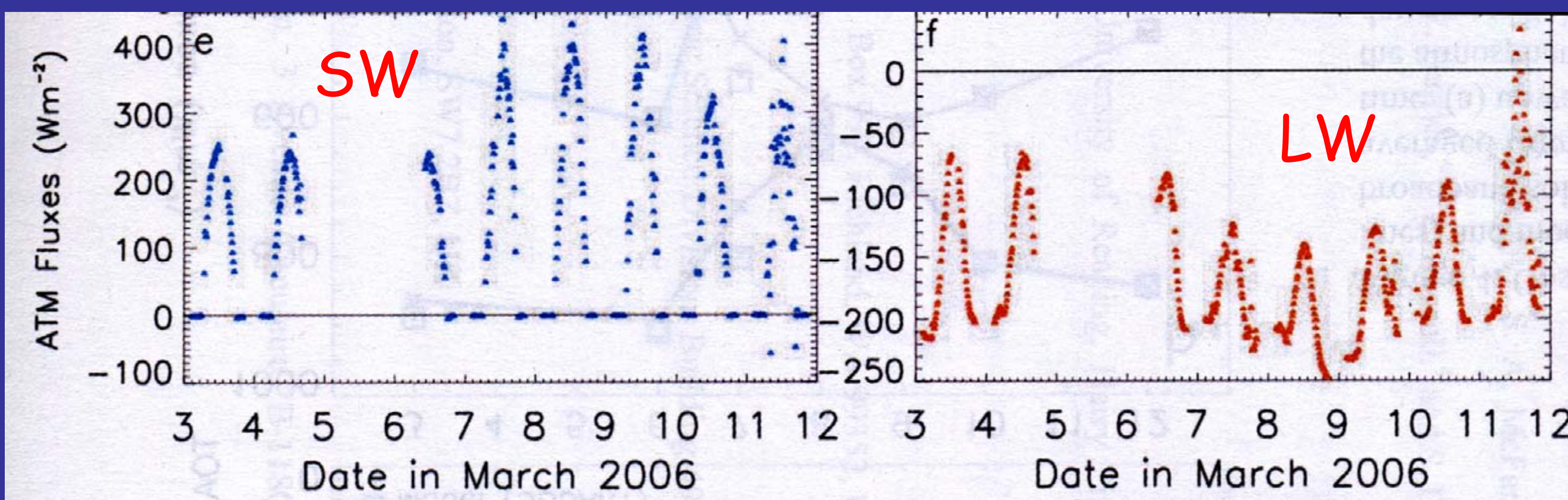



29 Mar 2000 (ARESE II)
Absorptance (surface to 7 km)
0.25
0.20
0.15
0.10
0.05
0.00
ST-DISORT
Streamer
CRM
SBDART
Fu-Liou
CHARTS
MODTRAN4
RRTM_SW
observed

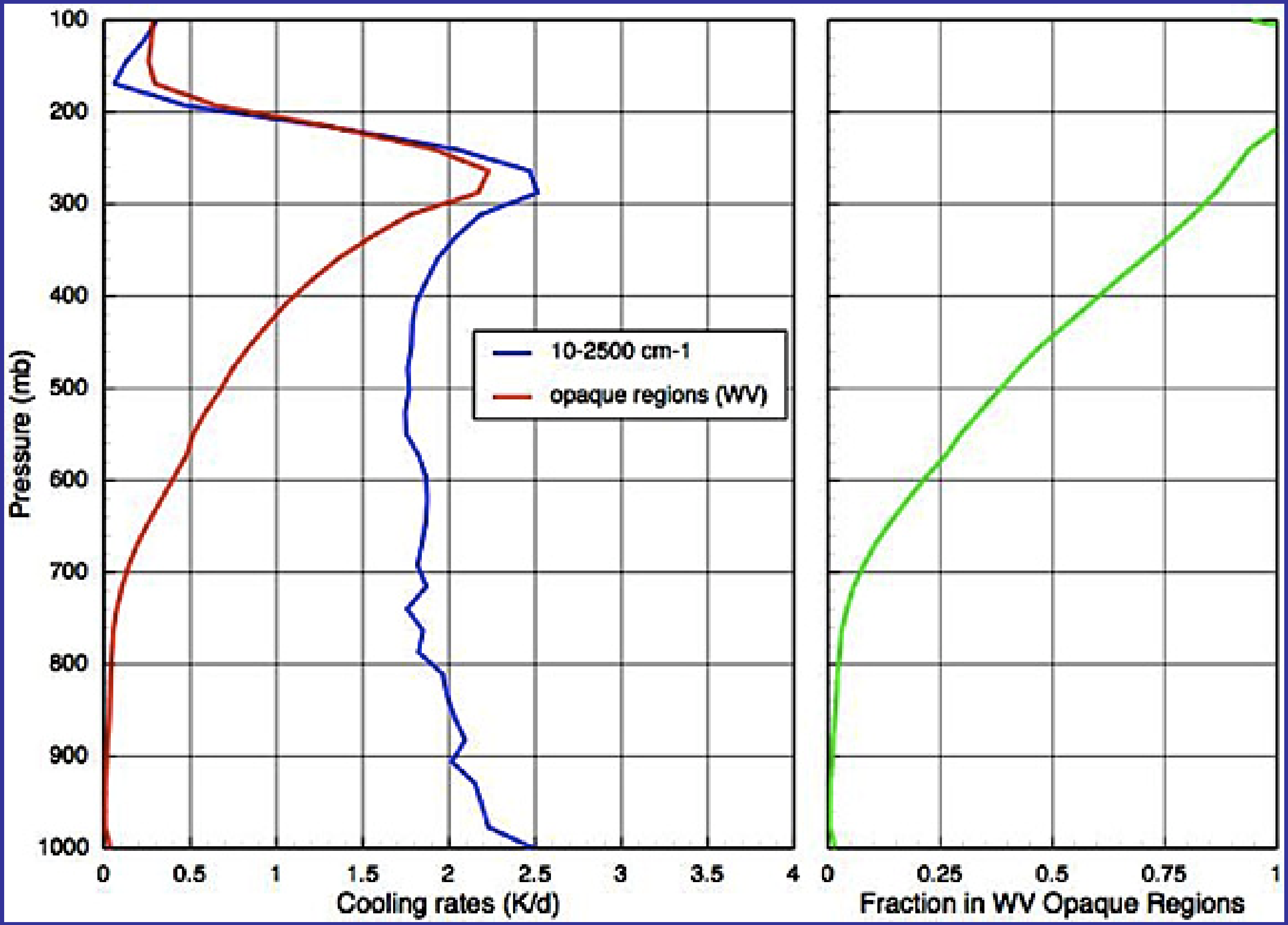
Niger: ARM Mobile Facility + GERB got first long-term radiative heating dataset!



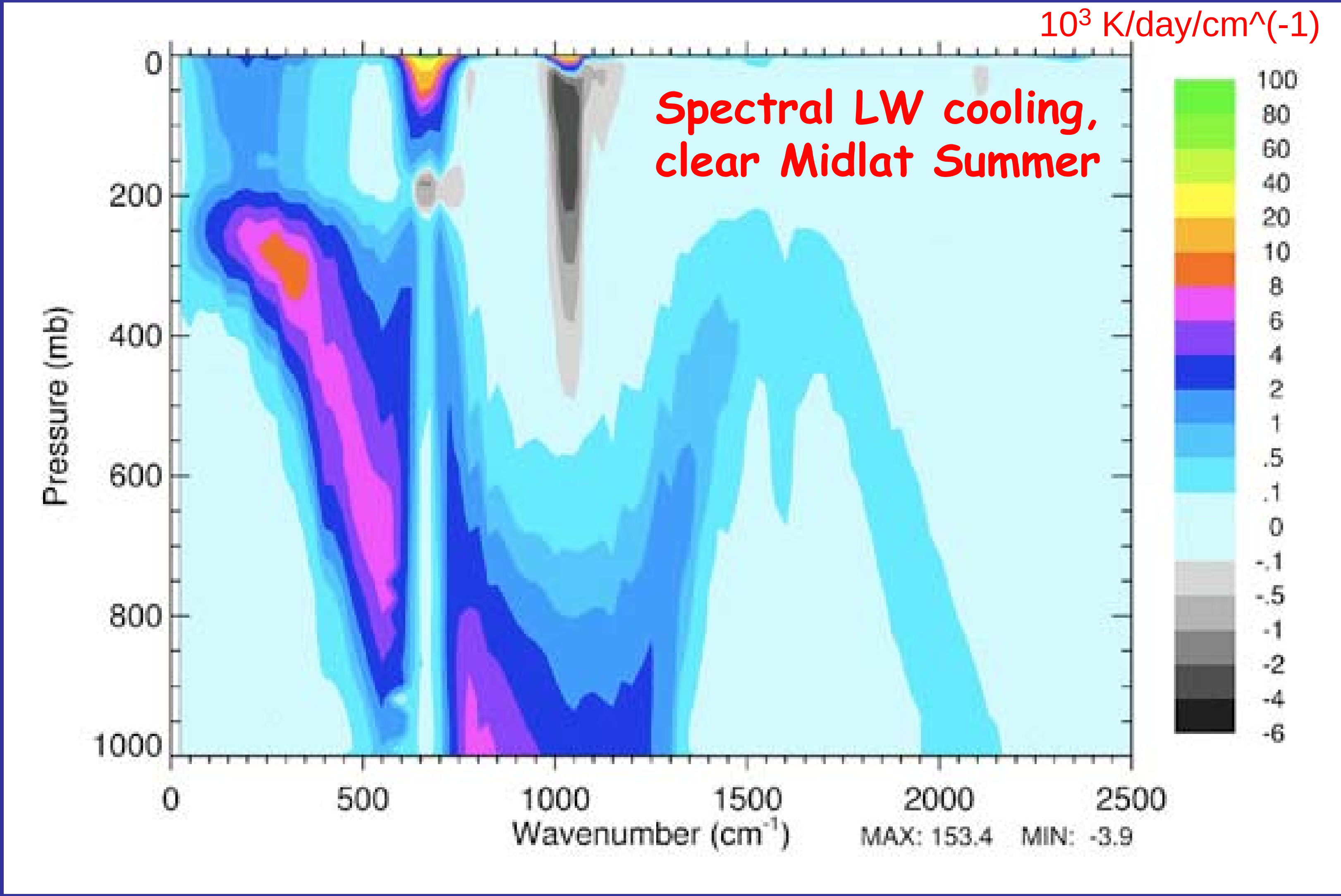
TOA to surface rad'n flux diffs vs. time



Far-IR dominates upper trop cooling rate

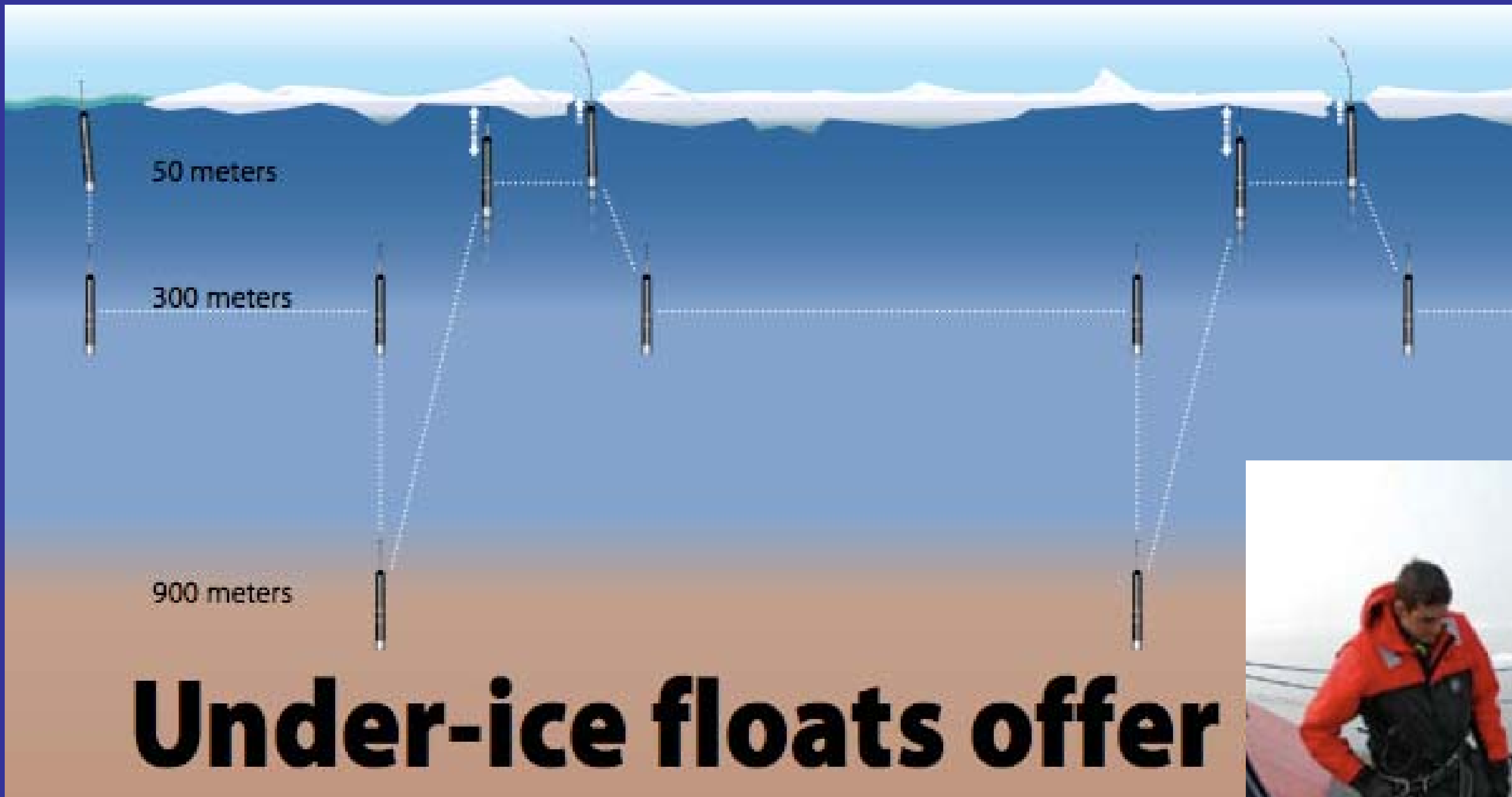


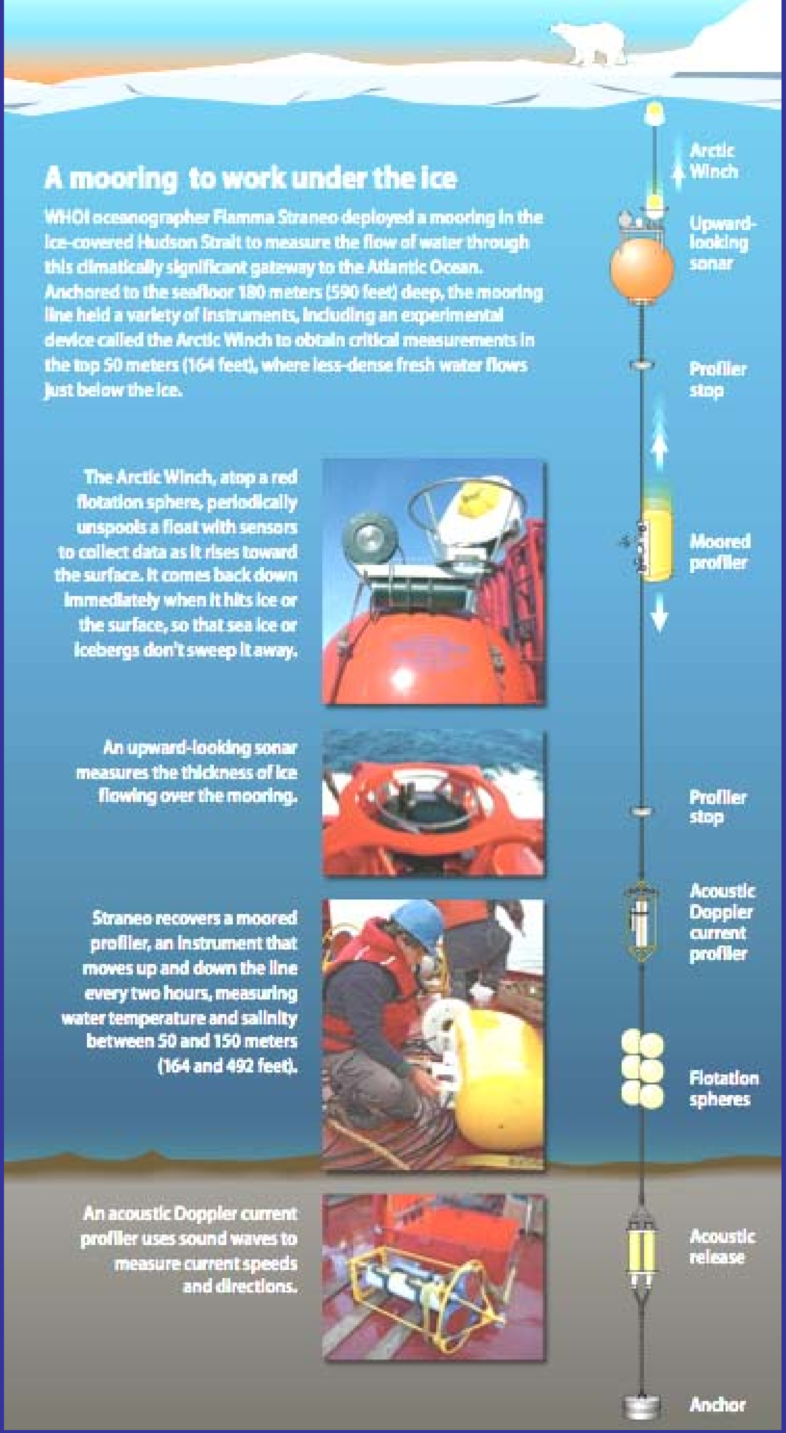
Clough plot shows where cooling is located spectrally — the far IR



Future: Radiative Heating in Underexplored Bands Campaigns (Barrow, Chile, ...)

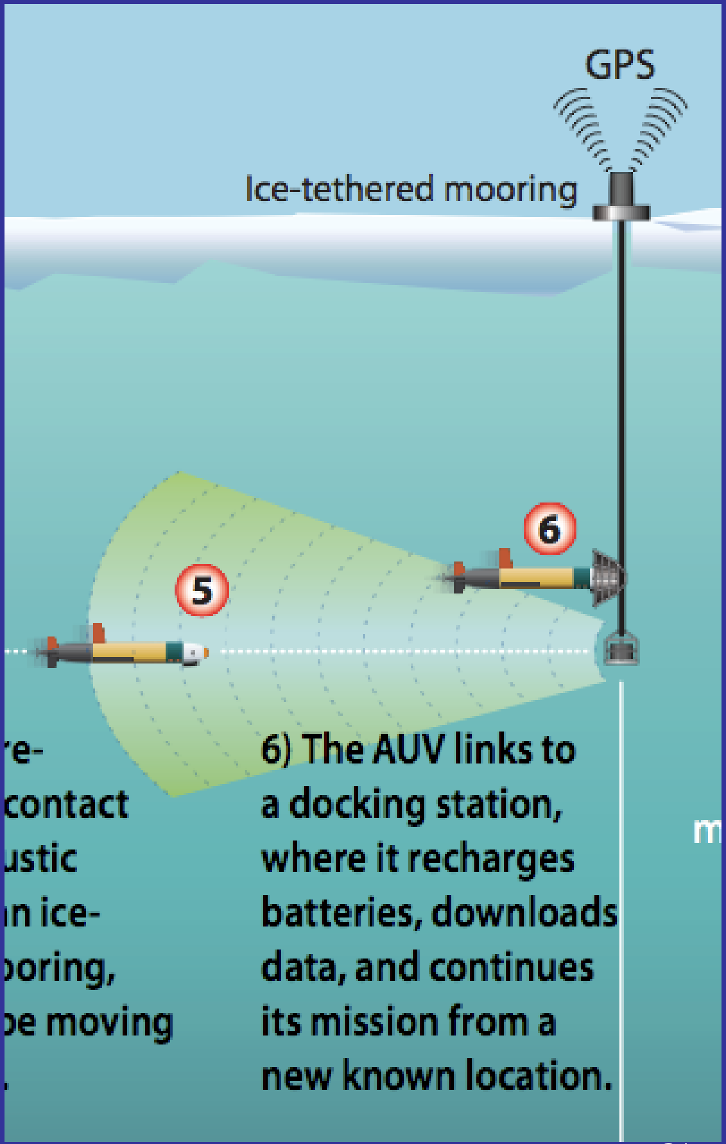
Oceanographers are far ahead in profiling



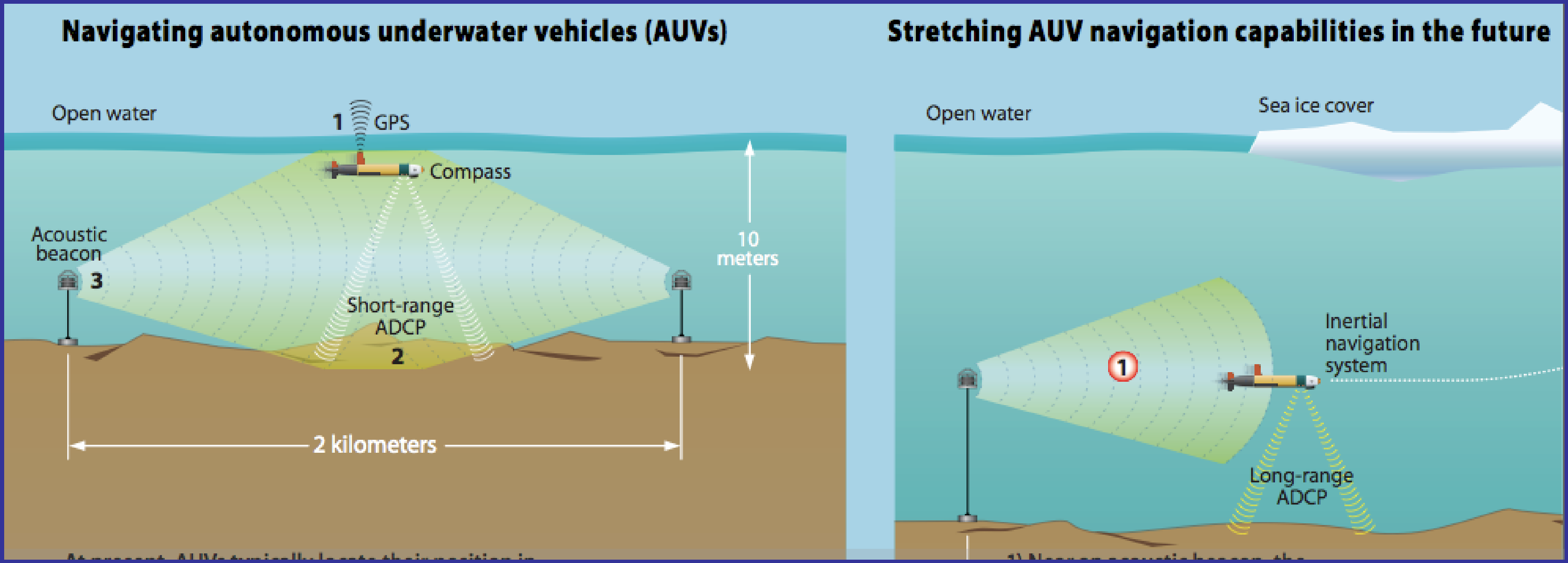


Underice profiling mooring

Autonomous underwater vehicle navigates by GPS, acoustic Doppler, beacons, and dead reckoning

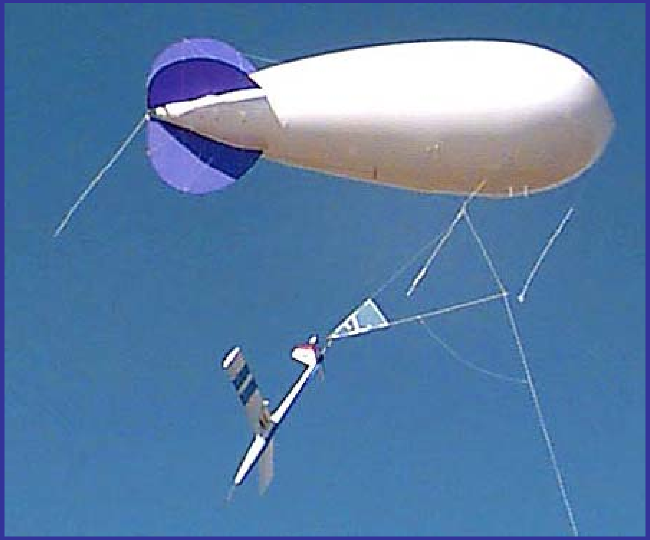


Autonomous underwater vehicle - 2



Autonomous abovewater vehicles

stacked UAVs (below, in, above cloud)



balloon-launched small UAV

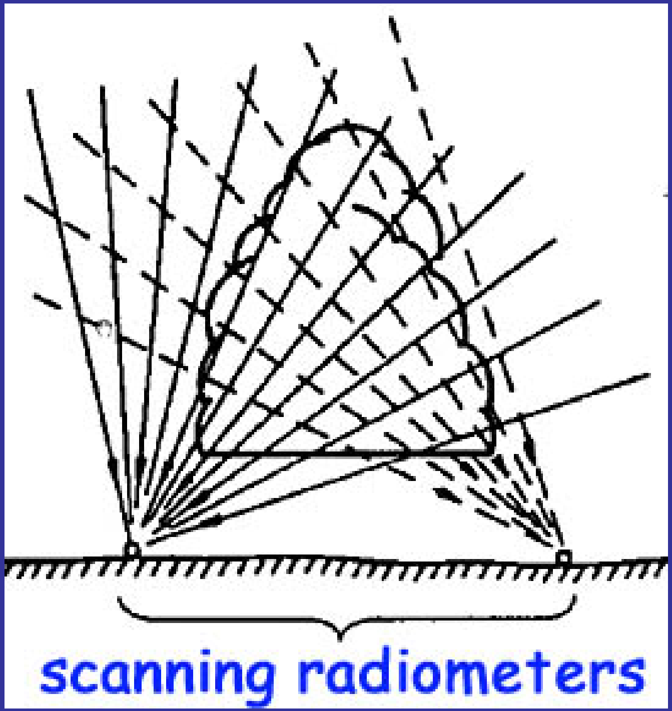
Tethered (and un-) balloons underexploited

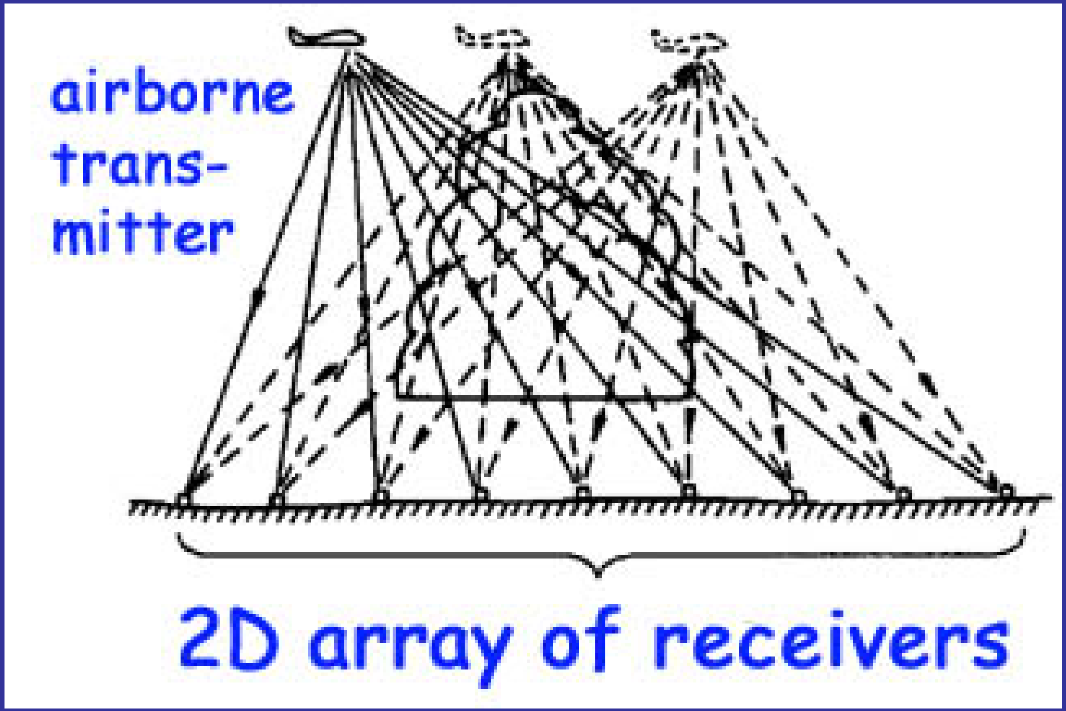
ditto for
tall towers

ARM's routine flights could be entrained to measure rad heat profile

Now we will do the same for clouds!

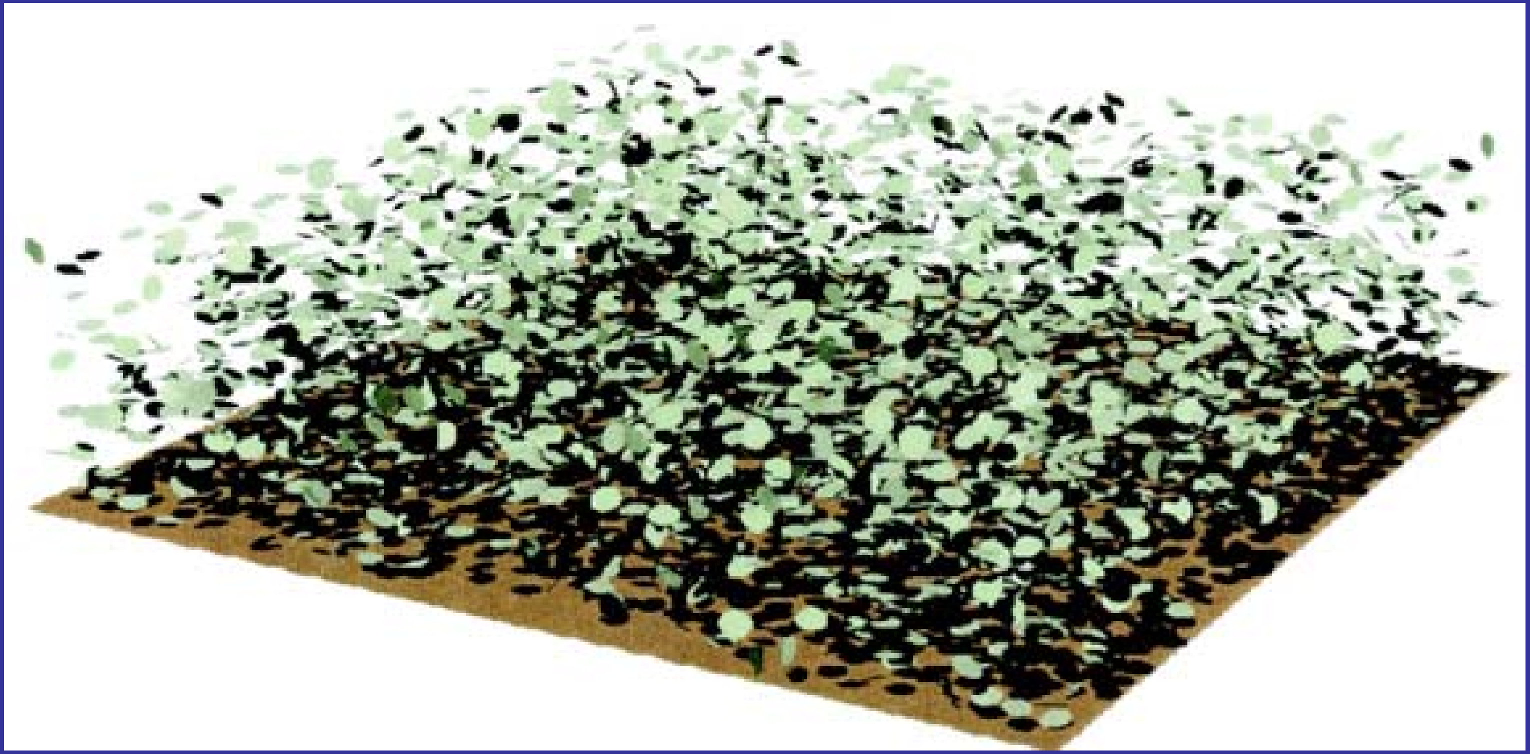
Microwave cloud tomography: one way to get input needed for modeling rad heat profile





Warner's 1986 setup

A potential trial run: measure rad heat profile in forest canopies



Other things on the horizon

- Net flux instruments
- Small/light/cheap instruments
- Stratospheric balloon radiometers
- Improved statistical sorting of data
- Radiometersondes (spinning dropsondes?)